MA 49: Terahertz dynamics

Time: Thursday 15:00–16:30 Location: EB 202

MA 49.1 Thu 15:00 EB 202

Exploring magneto-optical interactions in rare-earth doped garnets by multi-dimensional THz spectroscopy — •Shovon Pal[1], Christian Tzschaschel[1], Takuya Satoh[2], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland. — [2]Kyushu University, Japan.

Multi-dimensional nonlinear spectroscopy is a very powerful tool that bears the potential to unravel the dynamics (both coherent and incoherent) and coupling of elementary interactions in solid-state systems. Due to low THz photon energies, these radiations provide a means to address electronic states by resonant excitation and detection of electronic states having energy differences in the meV range. Typically, intense THz pulses have the potential to induce ultrafast electric- or magnetic-switching operations that last from a few tens of femtoseconds to a few tens of picoseconds. For example, observation of multiple harmonics and quantum coherences in semiconductor systems and canted antiferromagnets. Further, both energy and time scales of THz radiation favors fundamental investigations on magneto-optical interplay at the quantum level. Garnets, in particular, provide a platform towards the development of technologically relevant material for magneto-optical spintronic devices. On doping with rare-earth elements, they show an unusual strong excitation of magnetization precession with a frequency in the THz regime, resulting from the exchange interaction between rare-earth and transition metal elements. We present our direct observation of this nonlinear magneto-optical interaction at 0.5 THz in a Gd, Yb-doped bismuth iron garnet via two-dimensional THz time domain spectroscopy.

MA 49.2 Thu 15:15 EB 202

Antiferromagnetic resonance in Mn2Au driven by Néel spin orbit torque — •Nilabha Bhattacharjee, Stanislav Bodnar, Alexey Sapozhnik, Olena Gomonay, Martin Jourdan, and Jure Demsar — Johannes Gutenberg University, Mainz, 55099, Germany

Ultrafast spin dynamics in antiferromagnetic (AFM) materials has become a topic of immense interest due to its possible potential applications in spintronics. The AFM material Mn2Au, which is of huge prospect due to its high Néel temperature (~1600K) [1], strong spin-orbit coupling and high conductivity, requires a better understanding of its microscopic properties.

A comprehensive study of complex optical conductivity in thin c-axis grown Mn2Au films is presented in this work by means of time-domain THz spectroscopy.Thin (40 nm) Mn2Au films are grown by rf- sputtering on a 8 nm thick Ta buffer layer, deposited on a 500 micron thick R-cut sapphire substrate [2]. A damped antiferromagnetic resonance (AFMR) mode at 1THz (at room temperature) is observed in the conductivity data of Mn2Au by fitting with Drude-Lorentz model. A systematic study of temperature dependence of AFMR is been performed and a shift of the AFMR towards lower frequency is observed as the temperature varies from 5K to 450K. Here we also propose Néel spin orbit torque [3] driven mechanism of the in-plane AFMR mode in Mn2Au.

[1] S Khmelevskyi et al., App. Phys. Lett., 93, 162503 (2008). [2] M Jourdan et al., J. Phys. D: Appl. Phys., 48, 385001 (2015). [3] J. Železný et al., Phys. Rev. Lett. 113, 157201 (2014).

MA 49.3 Thu 15:30 EB 202

Narrow-band THz spin dynamics in ferromagnetic metallic thin films — •Stefano Bonetti — Stockholm University, 10691 Stockholm, Sweden

The interaction between magnetism and light is receiving considerable interest in recent years, after the groundbreaking experiments that showed that ultrashort (∼100 fs) infrared light pulses can be used to demagnetise or even switch the magnetisation of thin film ferromagnets. However, to date no clear and commonly accepted understanding of the fundamental physical processes governing the ultrafast magnetization has been reached., partly because accurate modelling of the infrared fs laser-induced highly non-equilibrium state remains a key obstacle.

In this talk, I will present recent experiments where we used strong THz fields, rather than infrared pulses, to excite ultrafast magnetisation dynamics in thin film ferromagnets, and probed it with the time-resolved magneto-optical Kerr effect. We used narrow-band THz pulses produced at the High-Field High-Repetition-Rate Terahertz facility @ ELBE (TELBE) to drive magnetisation dynamics in an amorphous CoFeB sample. Our results show that demagnetisation is strongly dependent on the frequency of the THz pulses and that there is a competition with frequency dependent re-magnetising effects, and that the number and type of defects affect the process. Our measurements illustrate the relation between charge- and spin-dependent scattering of conduction electrons, deepening our understanding of ultrafast spin dynamics.

MA 49.4 Thu 15:45 EB 202

Optical generation of femtosecond spin-current pulses in metallic multilayers: optimizing the efficiency — •Alexey Melnikov[1,2], Liane Brandt[1], Mirko Ribow[1], Niklas Liebing[1], Ilya Razdolski[2], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics — [2]Fritz Haber Institute of the Max Planck Society, Department of Physical Chemistry

The key challenge in a rapidly emerging field of modern spintronics consists in the push from the GHz to THz domain. In particular, it requires the development of techniques for the generation of femtosecond spin current (SC) pulses. With the help of magneto-induced second harmonic generation (mSHG) in the back pump-front probe scheme, we have demonstrated long-range spin transport on a femtosecond timescale upon laser excitation of the Fe film in epitaxial Fe/Au bilayers [1]. Later on, in Fe/Au/Fe tri-layers, this technique allowed us to demonstrate 250 fs-short SC pulses and attribute their origin to the non-thermal spin-dependent Seebeck effect at ferromagnet/normal metal interfaces [2]. Here, using both mSHG and magneto-optical Kerr effect detection in similar structures with variable thickness of the Fe emitter, we optimize the excitation of THz standing spin waves [3] and obtain new insights into the underlying electron and spin dynamics. In particular, from the SC generation efficiency dependence on the emitter thickness peaking at 4 nm, we estimate the escape depth of hot majority electrons in Fe of about 2 nm. [1] A. Melnikov et al., PRL 107, 076601 (2011); [2] A. Alekhin et al., PRL 119, 017202 (2017); [3] I. Razdolski et al., Nature Commun. 8, 15007 (2017).

MA 49.5 Thu 16:00 EB 202

Terahertz laser-induced spin waves in metallic multilayers: tuning the frequencies — •Liane Brandt[1], Mirko Ribow[1], Niklas Liebing[1], Ilya Razdolski[2], Georg Woltersdorf[1], and Alexey Melnikov[1,2] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics — [2]Fritz Haber Institute of the Max Planck Society, Department of Physical Chemistry

Recently, in Fe/Au/Fe tri-layers we have demonstrated the excitation of sub-THz perpendicular standing spin waves (PSSW) in the 14 nm-thick Fe layer studied by the time-resolved magneto-optical Kerr effect in a back pump-front probe scheme [1]. This high-frequency spin dynamic is driven by interface-confined spin transfer torque (STT) exerted by 250 fs-short spin current pulses generated in the optically excited opposite Fe layer [2]. To tune the PSSW frequencies, we fabricated an epitaxial Fe/Au/Fe structure with continuously varying Fe collector thickness from 1 to 17 nm. We demonstrate efficient STT-driven excitation of PSSWs with frequencies up to 2 THz corresponding to spin-wavelengths of 2 nm. Signatures of the higher-order PSSWs with even higher frequencies (up to 5 THz) are also observed. We analyze the PSSW dispersion, damping, and amplitudes in the time domain as well as their dependence on the collector thickness and discuss new insights into the STT-induced THz spin dynamics.

[1] I. Razdolski et al., Nature Commun. 8, 15007 (2017)

[2] A. Alekhin et al., PRL 119, 017202 (2017)

MA 49.6 Thu 16:15 EB 202

Influence of the electron scattering lifetime onto THz-spintronic experiments — Laura Scheuer[1], Sascha Keller[1], Garik Torosyan[2], Marco Battiato[3], René Beigang[1,2], and •Evangelos Th. Papaioannou[1] — [1]Department of Physics and Research Center Optimas, TU Kaiserslautern, Kaiserslautern, 67663, Germany — [2]Photonic Center Kaiserslautern, Kaiserslautern, 67663, Germany — [3]School of Physical and Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore 637371, Singapore

We show how the THz-E-field amplitude and the bandwidth of the

THz radiation, generated by spintronic Fe/Pt bilayer emitters [1], can be optimized by the crystal structure of Pt. By changing the growth parameters, Pt can grow along different crystallographic directions resulting in different degrees of epitaxy on top of Fe. Accordingly, the electron-phonon/defect scattering lifetime at the Fe/Pt interface is modified which influences directly the emitted THz spectrum. We present a theoretical model which correlates the loss of energy of the hot electrons, with the ISHE current that causes the THz emission. By taking into account the response function of the THz detector we describe the influence of the crystal structure of Pt onto the THz signal shape and spectrum. We compare our calculations with experimental data obtained from sample series of Fe(2-12nm)/Pt(2-6 nm).

[1]G. Torosyan et al., arxiv.org/abs/1707.08894 (2017)